ECEN 150 Lab 7 – Superposition and linearity

Name: Brodric Young

Purposes: (46 points total)

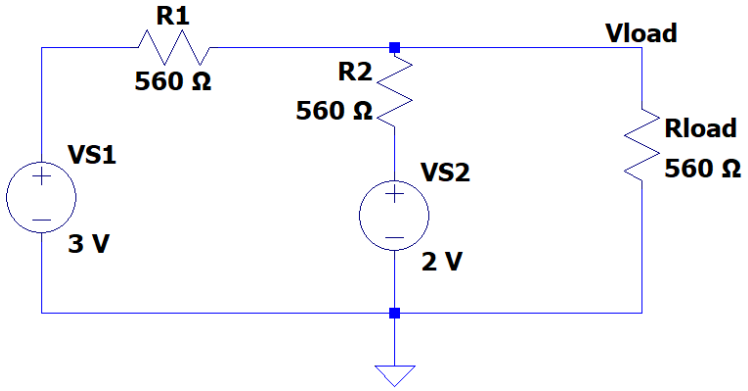
- Construct and measure a linear and non-linear circuit
- Experimentally show that superposition applies to linear circuits
- Experimentally show that superposition is invalid for non-linear circuits
- Learn to use Excel to create simple plots

Procedure:

Part 1. Superposition on a linear circuit

Step 1: Construct the circuit.

- Grab three 560 Ω resistors.
- Construct the circuit below on a breadboard using minimal or no wires.



Step 2: Measure Vload using the principles from superposition

- Measure Vload and **record the value in the table** below under "Complete circuit".
  - *Hint: it should be between 1.5 – 1.8 V.
- Superposition "Step A:" VS1 on; VS2 off.
  - Disconnect the VS2 source. Replace it with a wire (short).
  - **Record** the measured Vload in the table under "Step A".
- Superposition "Step B:" VS1 off; VS2 on.
  - Reconnect VS2 and ensure it is set to 2 V.
  - Disconnect the VS1 source. Replace it with a wire (short).
  - **Record** the measured Vload in the table under "Step B".

(6 points)	**VS1**	**VS2**	**Measured V_{load}**
Complete circuit	3 V	2 V	1.635V
Step A	3 V	0 V (replace with a short)	0.983V
Step B	0 V (replace with a short)	2 V	0.668V

Question 1: What is the sum of $V_{load,A}$ and $V_{load,B}$? (show your measured values & the result)

$V_{load,A} + V_{load,B} =$ 1.651 (1 point)

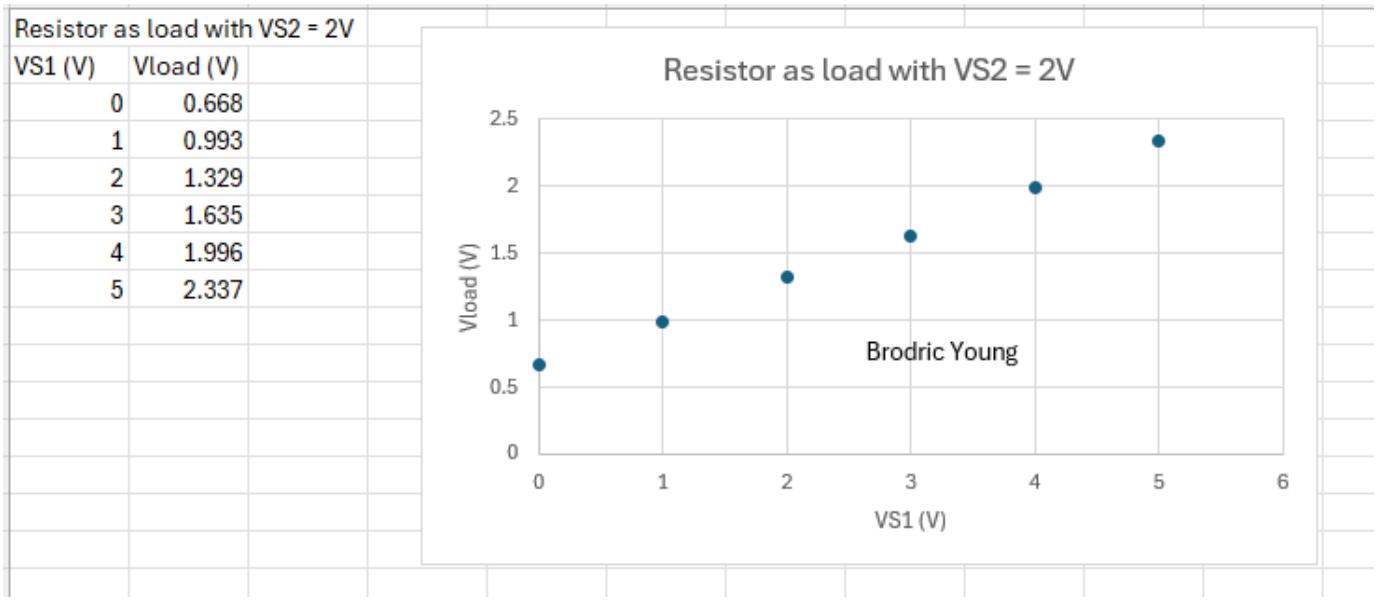
Question 2: Does the result from Question 1 match the "Complete circuit" value? (yes/no)

Yes (1 point)

Step 3: Experimentally determine if the circuit is linear.

- Reconnect the circuit as in the beginning (see schematic on Page 1).
- Keeping VS2 at 2 V, vary VS1 from 1 V – 5 V in 1V step sizes. Measure "Vload" for each VS1 value. **Record your values in a new Excel sheet** as in the example below. See the Appendix of this document for help.
    - *The value for VS1 = 0 V should come from "Step B" above; **the supply cannot be set to 0 V using the knob**.
    - Your value at VS1 = 3 V should match your "Complete Circuit" value from above.
- Plot your data in Excel. See the Appendix in this document if you need help. It should have a trend similar to that shown in the example, *but the values will be different.*
    - Ensure that you have the **same axis titles and graph titles** as the example below.
    - **Add your name** using a text box. It should have **a transparent fill**, as shown.

Paste a screenshot from your Excel results here (similar to the example below, showing the **data table, graph, and your name in a transparent text box**). Delete the example. (5 points)



Question 3: Is this circuit linear? How do you know? Use at least one complete sentence and include discussion of your Excel graph from above. (2 points)

Yes the circuit is linear because the data points form a straight line meaning its linear.

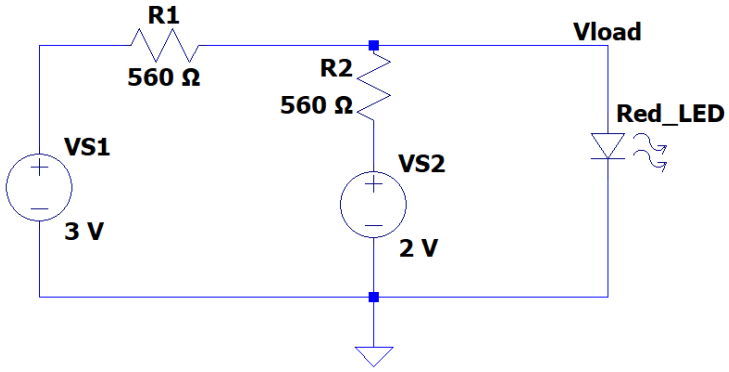
Question 4: Is superposition valid for this circuit? Explain why. Be sure to discuss linearity and your results from Questions 1, 2, and 3. (3 points)

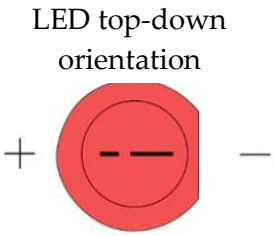
Yes superposition is valid because it's linear. You can split the circuit into the individual sources and then add them up and it's the same as measuring with all the sources on because it's linear.

Part 2. Superposition on a non-linear circuit

Step 1: Construct the circuit.

- Obtain a red LED. Replace the Rload resistor with the LED as illustrated below.
  - Note that the **flat side** of the LED should connect to ground.
  - The LED should now be glowing once the circuit is complete.





Step 2: Measure Vload using the principles from superposition

- Measure Vload and **record the value in the table** below under "Complete circuit".
- Superposition "Step A:" VS1 on; VS2 off.
  - Disconnect the VS2 source. Replace it with a wire (short).
  - **Record** the measured Vload in the table under "Step A".
- Superposition "Step B:" VS1 off; VS2 on.
  - Reconnect VS2 and ensure it is set to 2 V.
  - Disconnect the VS1 source. Replace it with a wire (short).
  - **Record** the measured Vload in the table under "Step B".

(6 points)	**VS1**	**VS2**	**Measured V_{load}**
Complete circuit	3 V	2 V	1.675V
Step A	3 V	0 V (replace with a short)	1.479V
Step B	0 V (replace with a short)	2 V	1.007V

Question 5: What is the sum of $V_{load,A}$ and $V_{load,B}$? (show your measured values & the result)

$V_{load,A} + V_{load,B} =$ 2.486V (1 point)

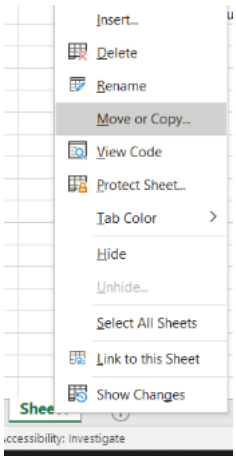
Question 6: Does the result from Question 5 match the "Complete circuit" value? (yes/no)

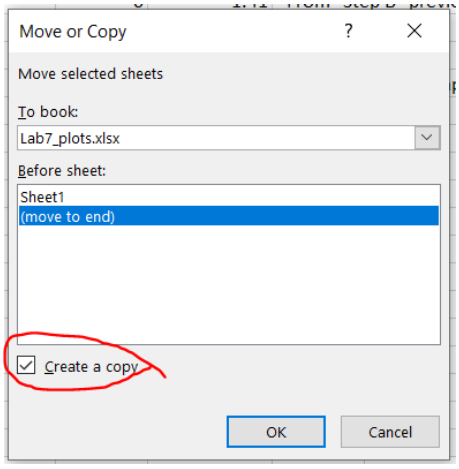
No (1 point)

Step 3: Experimentally determine if the circuit is linear.

- Reconnect the circuit as in the beginning (see schematic on Page 3).

- Make a copy of your existing Excel sheet so that you can update your graph and data using the LED circuit values:
    - Right click on the "Sheet 1 tab" at the bottom of the Excel screen.
    - Click "Move or Copy"
    - Ensure that "Create a copy" is checked, then click OK.
    - You should now see a new sheet called "Sheet 1 (2)". Optional: rename the tabs to something more meaningful using the right click menu.



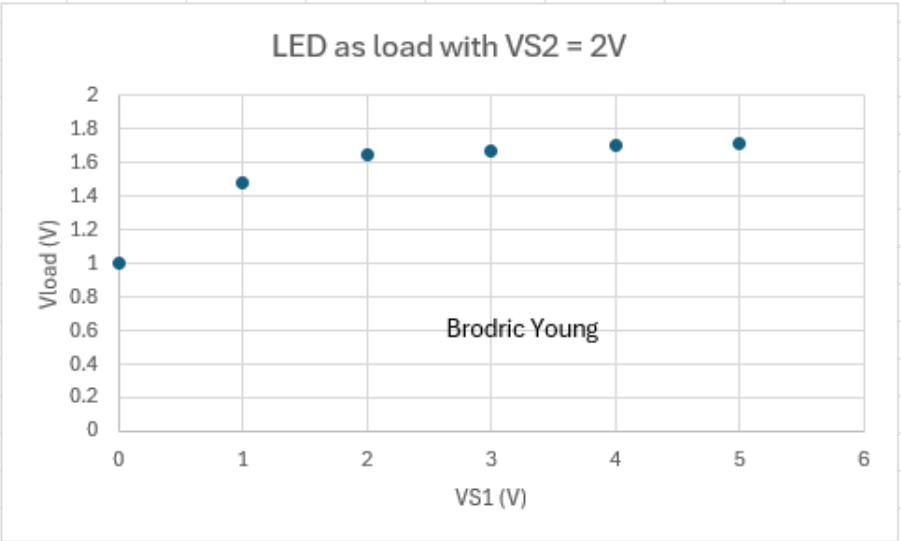


- Keeping VS2 at 2 V, vary VS1 from 1 V – 5 V in 1V step sizes. Measure "Vload" for each VS1 value. **Record your values in the copied Excel tab, replacing the old values**.
    - *The value for VS1 = 0 V should come from *Part 2* "Step B" above.
    - Your value at VS1 = 3 V should match your "Complete Circuit" value from above.
- The copied plot should update as you change values. It should have a trend similar to that shown in the example, *but the values will be different.*
    - **Rename your plot and axis titles** as shown in the example below.
    - **Ensure your name is visible in a transparent box, as before.**

Paste a screenshot from your Excel results here (similar to the example below, showing the **data table, graph, and your name in a transparent text box**). Delete the example. (5 points)

LED as load with VS2 = 2V

VS1 (V)	Vload (V)
0	1.007
1	1.48
2	1.645
3	1.675
4	1.702
5	1.72



Question 7: Is this LED circuit linear? How do you know? Use at least one complete sentence and include discussion of your LED Excel graph from above. (2 points)

No the circuit is not linear because the data points on the graph curve in an exponential way rather than linearly.

Question 8: Is superposition valid for this circuit? Explain why. Be sure to discuss linearity and your results from Questions 5, 6, and 7. (3 points)

No, superposition is not valid for this circuit because it's exponential rather than linear. If you measure the voltage, it will not be the same as summing the contributions of the individual sources because of its exponential behavior.

*****To pass off your circuit, demo it to the TA or instructor and take Lab 7: Quiz 1*****

Part 5. Conclusions statement.

Write a brief conclusions statement that discusses all of the original purposes of the lab. Please use complete sentences and correct grammar to express your thoughts on how you fulfilled the purposes of the lab:

Purposes (repeated):

- Construct and measure a linear and non-linear circuit
- Experimentally show that superposition applies to linear circuits
- Experimentally show that superposition is invalid for non-linear circuits
- Learn to use Excel to create simple plots

Conclusions (10 points):
For this lab we wanted to compare and show the differences between a linear and non-linear circuit, in this case for our non-linear circuit we used an exponential one. We did this by constructing a circuit with resistors and two voltage sources then measuring the output voltage on the circuit while keeping one source constant and incrementing the other source by 1V intervals to get data points and create a graph. We also used superposition by turning each source off in turn and then adding the output voltage and comparing with our measured value. We then did the same for a new circuit replacing one resistor with an LED which is exponential. With only resistors, the graph was a straight line meaning its linear, and then sum of the individual sources was the same as our measured value. For the LED circuit, the graph was an exponential curve meaning it's non-linear, and the sum of the individual sources was not equal to our measured value. We also learned to use Excel to create the simple plots of our data and see the graphs.

Congratulations, you have completed Lab!
You may now submit this document.

Appendix: Using Excel to graph data

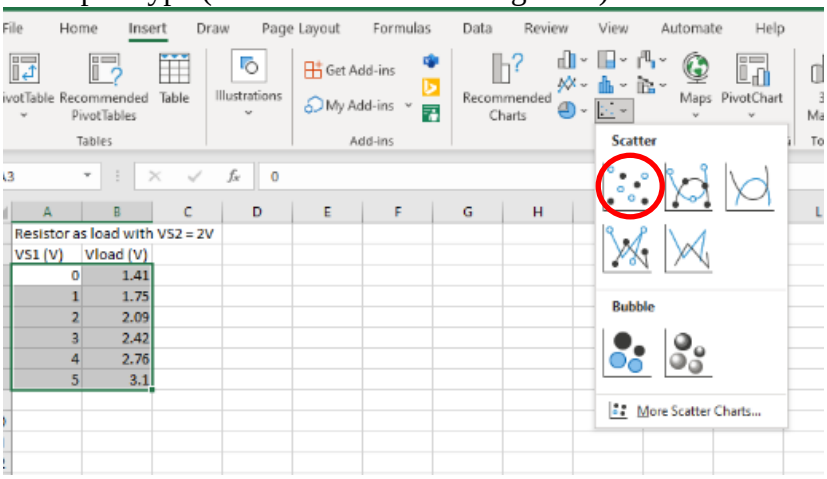
Recording data:

1. Open Excel and create a new "Blank Workbook."
2. In a cell near the top (select cell A1) type a short phrase to remind you what this data represents (something like: "Resistor as a load with VS2 = 2V")
3. Under that (select cell A2), type a heading for your VS1 values (something like: "VS1 (V)")
4. Next to that (cell B2), enter a heading for your measurement values (something like: "Vload (V)")
5. Populate the column under the VS1 heading with the VS1 values you'll be setting. (select each cell and type the numeric value).
6. Record the measured data under the Vload column.
7. It should now look something like this:

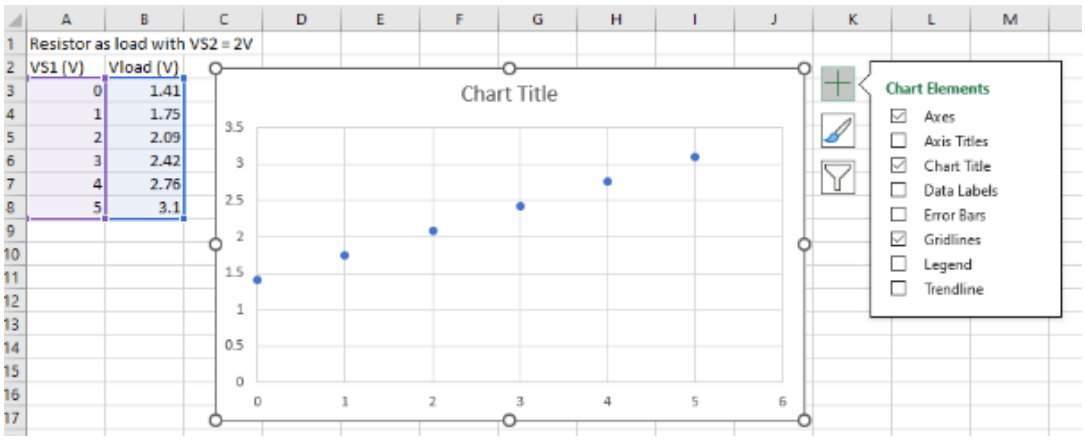
	A	B	C
1	Resistor as load with VS2 = 2V		
2	VS1 (V)	Vload (V)	
3	0	1.41	
4	1	1.75	
5	2	2.09	
6	3	2.42	
7	4	2.76	
8	5	3.1	

Graphing the data:

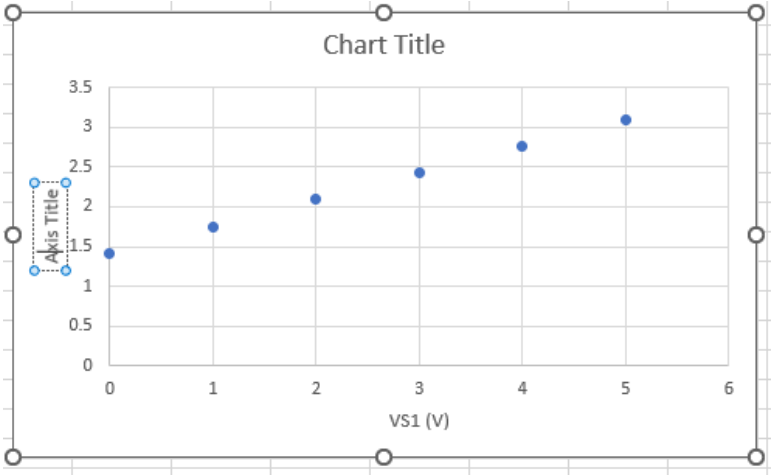
1. Select all of the data by doing a click-and-hold on the first data cell (A3) and dragging to the last data cell (B8).
2. Click the "Insert" tab, then in the "Charts" section click on the scatter plot icon. Then choose the scatter plot type (without lines connecting them).



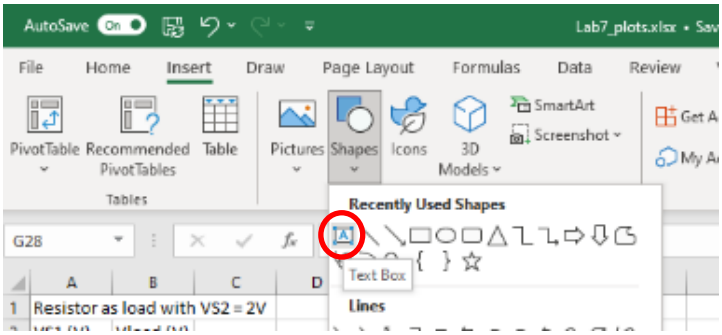
3. This will create a generic chart. You can click-and-hold on it to drag this chart near to your data for convenience.
4. Click on the chart, then click on the "+" sign off to the right of it to open the chart options menu.



5. Click the check box for "Axis Titles" to add them.
6. Double click on each axis title and the chart title to edit them.
    a. The X axis for this lab should be "VS1 (V)". The Y axis should be "Vload (V)".
    b. The chart title should be "Resistor as Load. VS2 = 2 V."



7. Now click the "Insert" tab → Shapes → Text box



8. Click on your graph to place a text box on it. Type your name in the box.
9. Right click on the text box. Choose the "Fill" drop down, then select "No Fill" to make it transparent.
10. You can now take a screenshot of the data and graph!